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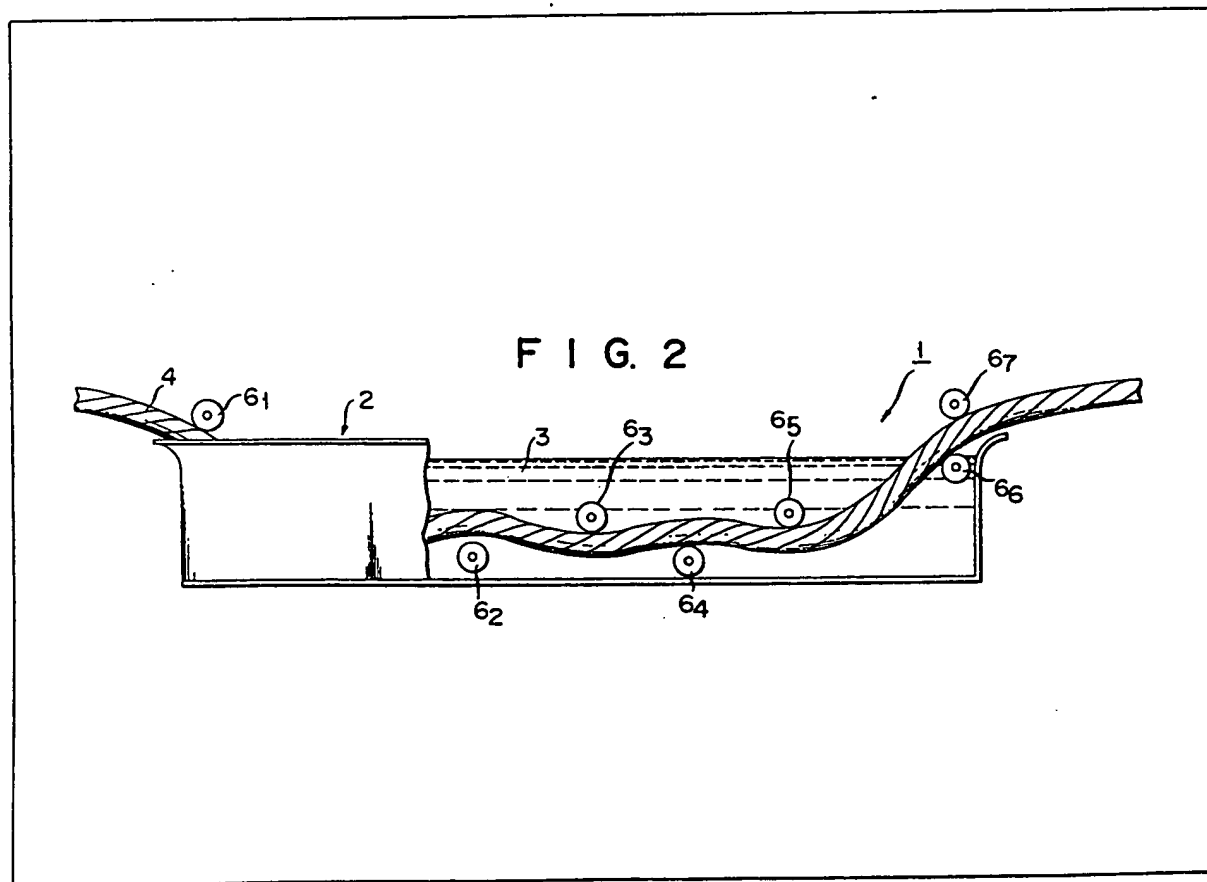
(54) A conductor for an electric  
power cable and a method for  
manufacturing the same

(57) A conductor for an electric power  
cable is constituted by a plurality of  
stranded conductive strands, at least  
one of the conductive strands being  
covered with an oxide film free from  
exfoliation.

Manufacturing the conductor  
includes the step of passing an  
uninsulated stranded conductor 4  
constituted by a plurality of stranded  
conductive strands through an  
oxidizing liquid 3. The stranded  
conductor passing through the liquid 3  
is curved to form gaps between the  
strands, and the oxidizing liquid 3 is  
caused to penetrate between the  
strands through the gaps to form  
oxide films on the surfaces of the  
strands.

The conductor may be formed of  
oxidized and unoxidized strands on th  
inside or outside of the conductor  
(Figs. 7, 8, 10 and 11 not shown) and  
built up of segments of strands (Figs  
9, 10 and 11).

The drawings originally filed  
were informal and the print  
here reproduced is taken from a  
later filed formal copy.



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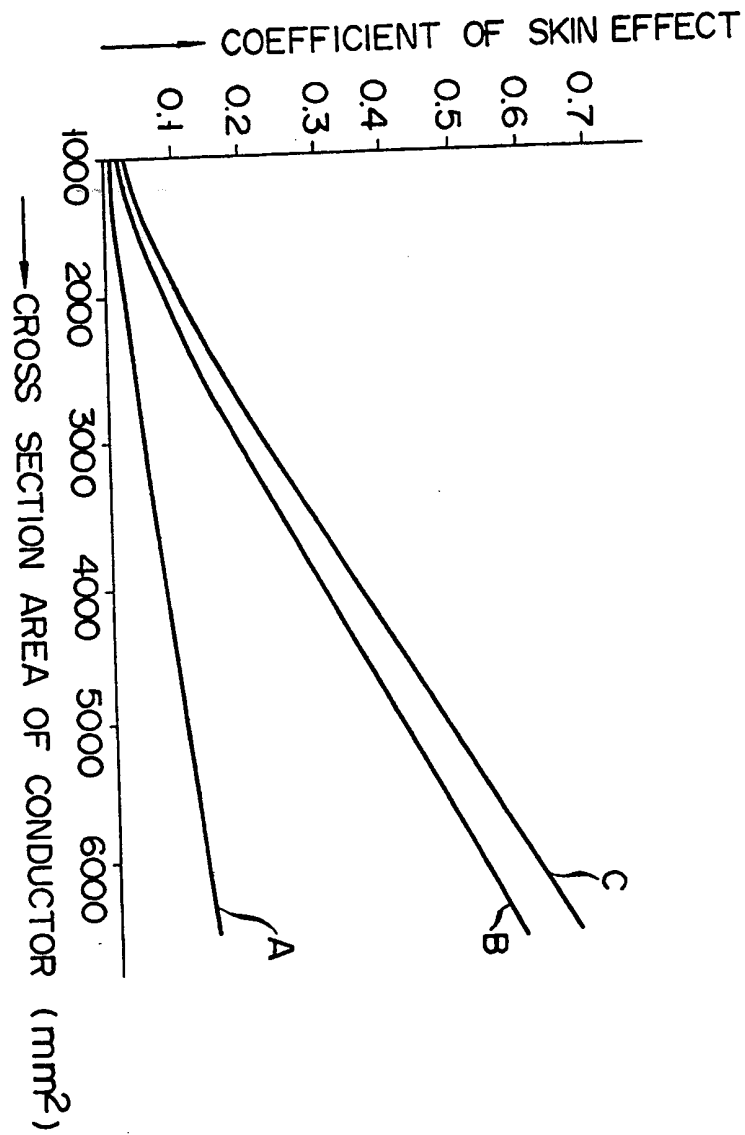


FIG. 1



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FIG. 5

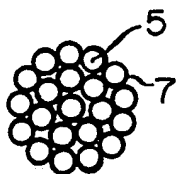


FIG. 6

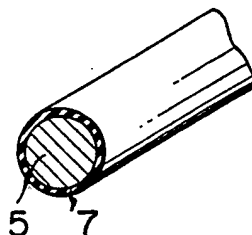


FIG. 7

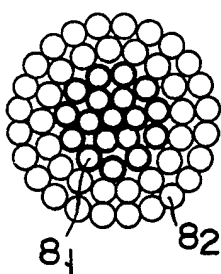


FIG. 8

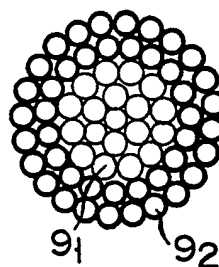


FIG. 9

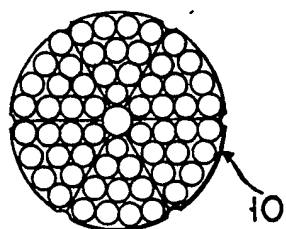


FIG. 10

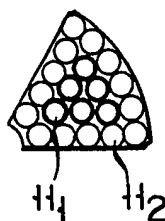
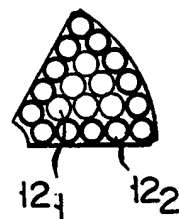


FIG. 11



## SPECIFICATION

**A conductor for an electric power cable and a method for manufacturing the same**

This invention relates to a conductor for cable, more specifically to a large-size conductor for electric power cable and a method for manufacturing the same.

Accompanying the remarkable increase in the electric power consumption, the amount of power transmission has been increasing steadily. With such increase of the power transmission capacity, large-size conductors for power cable have come into use. Recently, conductors with cross-sectional area of more than 2000 mm<sup>2</sup>, especially, 5,000 to 6,000 mm<sup>2</sup> have been put to practical use.

These large-size conductors, however, are subject to a significant defect — AC losses due to the skin effect, proximity effect, etc. Namely, the increase of the AC resistance due to the skin and/or proximity effects suppresses the increase of the transmission capacity. In order to reduce such AC losses, so-called multi-segmental conductors have been developed. The multi-segmental conductor may be obtained by preparing a small-size segment formed of shaped stranded conductor, applying the insulation over the segment, and laying up several such small-size stranded segments into a large-size conductor. Also developed has been an insulating-film-coated stranded conductor in which each strand is covered with an insulating film.

Fig. 1 shows skin effect characteristics of three conductors of different types with respect to the cross-sectional areas thereof. In Fig. 1, a characteristic curve A represents a case of an insulating-film-coated stranded conductor, while curves B and C represent cases of an oil-filled cable conductor and a pipe-type-oil-filled cable conductor, respectively. As is evident from Fig. 1, the insulating-film-coated stranded conductor is the lowest among others in the coefficient of skin effect for every cross-sectional area, and also in the increasing rate of the coefficient of skin effect relative to the increase in the cross-sectional area of the conductor. Namely, the larger the cross-sectional area becomes, the more favorable the insulating-film-coated stranded conductor becomes as compared with the other types.

The enamel coating method has been generally used for the insulation of a strand. This enamel coating method, however, has a drawback to be high cost. Also available is a method to form a surface oxide film on a strand by oxidizing the surface of every strand. In this method, each strand is individually immersed in oxidizing liquid to form an oxide film on the surface of the strand, for example. A plurality of such strands each covered with an oxide film are stranded to form a conductor for cable. In this case, however, the strands already covered with the oxide films are stranded by means of an external force, to cause a relatively large frictional force to occur between the strands in the course of stranding, thereby

exfoliating the oxide films on the surfaces of the strands.

Furthermore, there is a method to immerse a stranded conductor in oxidizing liquid to oxidize the surface of each strand. In such method, however, there is a drawback in the following that the strands are stranded tight at a stage where the conductor is immersed in the liquid, so that the oxidizing liquid will not be able to penetrate deep into the gap between the strands of the immersed conductor, thus oxidizing only the exposed surfaces of the strands at the superficial portions of the strands.

Accordingly, the object of this invention is to provide a low-cost conductor for cable, more specifically a large-size conductor for large capacity cable subject to reduced influences of the skin and/or proximity effects, and a method for manufacturing the same.

According to this invention, there is provided a stranded conductor constituted by a plurality of stranded conductive strands, at least one of the conductive strands being covered with an oxide film free from exfoliation.

Further, according to the invention, there is provided a method for manufacturing a stranded conductor comprising steps of passing a conductor constituted by stranded uninsulated conductive strands through oxidizing liquid while the conductor is curved to form gaps between the strands, thereby forming oxide films on the surfaces of the strands, and removing the gaps between the strands.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 shows the relationship between the cross-sectional areas of various conductors of different types and the coefficient of skin effect;

Fig. 2 shows the structure of an apparatus used in a process for executing the manufacturing method of this invention;

Fig. 3 is an enlarged perspective view of a stranded conductor to be subjected to an oxidation process as shown in Fig. 2;

Fig. 4 is a perspective view of a guide roller;

Fig. 5 is a cross-sectional view of the conductor after having undergone the oxidation process;

Fig. 6 is an enlarged perspective view of one of the strands of the conductor after having undergone the oxidation process;

Fig. 7 is a cross-sectional view showing another form of the conductor provided by the manufacturing method of the invention;

Fig. 8 is a cross-sectional view showing still another form of the conductor;

Fig. 9 is a cross-sectional view showing a further form of the conductor;

Fig. 10 is a cross-sectional view showing a form of a conductor segment constituting the conductor of Fig. 9; and

Fig. 11 is a cross-sectional view showing another types of the conductor segment as shown in Fig. 10.

Fig. 2 shows a process for illustrating the method for manufacturing a stranded conductor constituted by insulated conductive strands free from any exfoliated insulating oxide film, according to this invention. In Fig. 2, there is shown a step in which the conductor constituted by a plurality of stranded conductive bear strands passes through oxidizing liquid, thereby oxidizing the surfaces of the strands constituting the conductor.

Besides the aforesaid surface oxidizing process, though including various processes of the conventional manufacturing method, for example, conductor paying-off, taking-up, rinsing and drying processes, the method for manufacturing the stranded conductor of the invention is specially characterized by the oxidizing process, and the other processes are to be executed in accordance with the conventional systems. Accordingly, Fig. 2 illustrates only the oxidizing process, for the simplicity of the drawing.

In Fig. 2, numeral 1 designates an apparatus for the surface oxidation, in which a bath 2 is filled with oxidizing liquid 3. To facilitate the understanding of the construction of the apparatus, a wall member constituting the bath 2 is partially broken. Numeral 4 designates a conductor to be passed through the oxidizing liquid 3 for oxidation treatment. Fig. 3 shows an enlarged perspective view of part of the conductor.

As is evident from Fig. 3, the conductor 4 is constituted by a plurality of stranded conductive strands 5. A guide roller 6<sub>1</sub>, which has its axial central portion constricted as perspectively shown in Fig. 4, is rotatably attached to a frame (not shown) of the apparatus at right angles to the running direction of the conductor 4. Guide rollers 6<sub>2</sub>, 6<sub>3</sub>, 6<sub>4</sub> and 6<sub>5</sub> are rotatably attached between two facing walls of the bath 2 at positions vertically slightly shifted from one another. The guide rollers 6<sub>2</sub>, 6<sub>3</sub>, 6<sub>4</sub> and 6<sub>5</sub> tend to cause the conductor 4 passing through the oxidizing liquid 3 in the bath 2 to meander up and down. Guide rollers 6<sub>6</sub> and 6<sub>7</sub> direct the conductor 4 from the liquid 3 toward the outside. Although not shown, a feed mechanism (e.g. feed roller) for feeding the conductor 4 and a take-up mechanism (e.g. taken-up roller) are disposed, as required, on the left and right sides of the apparatus of Fig. 2, respectively. The guide rollers 6<sub>2</sub> to 6<sub>7</sub> may be of the same construction as that of the guide roller 6<sub>1</sub> as shown in Fig. 4.

Now there will be described the conductor manufacturing method of the invention employing the apparatus as shown in Fig. 2.

The conductor 4 is delivered from the feed mechanism (not shown) by the drive of the feed mechanism and take-up mechanism (not shown), and directed toward the oxidizing liquid 3 by the action of the guide roller 6<sub>1</sub> to pass through the liquid 3. When advancing in the liquid 3, the conductor 4 is wiggly directed as illustrated with its passage through each of the guide rollers 6<sub>2</sub> to 6<sub>5</sub> that are located at varied heights, moving

wavily or wiggly in the liquid 3. When the conductor 4 is curved by the guide rollers 6<sub>2</sub> to 6<sub>5</sub>, narrow gaps are created between the strands 5 constituting the conductor 4. The oxidizing liquid 3 penetrates through these gaps, thus reaching inner strands as well as strands in the vicinity of the outer periphery of the conductor.

Consequently, oxide films (e.g. CuO films for copper strands) are formed on the surfaces of not only the peripheral strands but also the inner ones. The oxidized conductor 4 is led to the outside by means of the guide rollers 6<sub>6</sub> and 6<sub>7</sub>, washed in water and dried in conventional methods, and then wound on the take-up mechanism (not shown). Alternatively, the conductor after drying may be delivered as it is for a cutting process to cut the conductor into suitable lengths, without being wound. Although not absolutely required, the washing and drying processes are preferably executed.

The gaps created between the strands 5 due to the curving by the guide rollers 6<sub>2</sub> to 6<sub>5</sub> in the oxidizing process must be removed after such process. Since the guide rollers 6<sub>2</sub> to 6<sub>5</sub> in the bath 2 are arranged with relatively small differences in height, the gaps between the strands 5 caused by the guide rollers 6<sub>2</sub> to 6<sub>5</sub> are narrow. Therefore, those gaps between the strands 5 may be removed by applying a tensile force created by the conventional winding process. Thus, the gaps between the strands 5 are relatively small, so that the removal of such gaps needs no great external force, only requiring the winding force applied to the conductor 4 in the winding process. The stress on the strands 5, therefore, is small, so that the oxide film on the surface of each strand 5 will never exfoliate.

The conductor 4 has its own righting moment, whereby the gaps between the strands 5 can also be removed without utilizing the winding force in the winding process.

When using a copper wire for the strand 5, the oxidizing liquid 3 used should preferably be a mixed solution of 5% sodium chlorite and 5% sodium hydroxide.

According to the manufacturing method of this invention, as described above, there may be provided the relatively inexpensive conductor 4 formed of the strands 5 with no exfoliated oxide film portion by delicately wiggly curving the conductor 4 passing through the oxidizing liquid 3 by means of the plurality of guide rollers 6<sub>2</sub> to 6<sub>5</sub> disposed with differences in height, causing the oxidizing liquid 3 to penetrate into the gaps between the strands 5 created by the curving, thereby effectively forming oxide films on the surface of the strands 5, and removing the gaps by the winding force applied to the conductor 4 in the winding process or by the righting moment of the conductor 4 itself where the winding process is omitted.

Fig. 5 shows a cross-sectional view of the conductor provided by the manufacturing method of the invention. As shown in Fig. 5, uniform and exfoliation-free oxide films 7 (represented by

circles described by thick lines in Fig. 5) are formed on the surfaces of all the strands 5, including the strands arranged in the inner part of the conductor as well as the strands on the outer periphery of the conductor. The conductor of such structure will hardly be subject to the skin effect, proximity effect, etc. Moreover, according to the manufacturing method of the invention, the conductor obtained may be relatively inexpensive because of the insulating films 7 formed on the individual strands 5 by oxidizing the surfaces thereof. Fig. 6 is an enlarged perspective view of one of the strands 5 of the conductor as shown in Fig. 5, for the clear illustration of the surface oxide film 7 on the strand 5. It is unnecessary to apply the surface oxidation to all the strands 5 that constitute the stranded conductor 4; a double-layer conductor with only inner strands 8<sub>1</sub> oxidized and outer strands 8<sub>2</sub> unoxidized, as shown in Fig. 7, may be obtained by previously applying, for example, oil to the peripheral strands among the strands forming the conductor 4 before the execution of the oxidation process, thereby preventing the surface of such oiled strands from being oxidized in the oxidation process. In contrast with this, as shown in Fig. 8, the conductor obtained may have its inner strands 9<sub>1</sub> unoxidized and outer strands 9<sub>2</sub> oxidized.

Also, this invention may be applied to a segmental conductor consisting of a plurality of sector-shaped segments, as shown in Fig. 9. Such conductor may be obtained by preparing segments 10 consisting of a plurality of stranded conductive strands 5 according to the manufacturing method of this invention, and then stranding a plurality of such segments together. Although the segmental conductor shown in Fig. 9 is formed of six segments 10, it is to be understood that there may also be obtained a conductor consisting of four, five, eight, nine, ten or twelve segments. The number of segments need not be limited to the number mentioned. Moreover, it is unnecessary to oxidize all the strands that constitute each segment; strands at only a specified portion are to be oxidized for insulation, like the case of Figs. 7 or 8. A segment shown in Fig. 10 has its inner strands 11<sub>1</sub>

insulated and peripheral strands 11<sub>2</sub> uninsulated. In contrast with this, Fig. 11 shows a conductor segment with inner strands 12<sub>1</sub> uninsulated and peripheral strands 12<sub>2</sub> insulated.

It is to be understood that the strands may be stranded in alternate directions or in one and the same direction.

#### 55 CLAIMS

1. A stranded conductor constituted by a plurality of stranded conductive strands, which comprises at least a conductive strand covered with an oxide film free from exfoliation.
2. A stranded conductor according to claim 1, wherein each of said conductive strand is a copper wire.
3. A stranded conductor according to claim 2, wherein said oxide film on said copper wire is cupric oxide formed by oxidizing the surface of said copper wire.
4. A method for manufacturing a stranded conductor comprising steps of passing an uninsulated stranded conductor constituted by stranded uninsulated conductive strands through oxidizing liquid while said stranded conductor is curved to form gaps between said strands, thereby forming oxide films on the surfaces of said strands, and removing said gaps between said strands.
5. A manufacturing method according to claim 4, wherein each of said conductive strand is a copper wire, and said oxidizing liquid is a mixed solution of 5% sodium chlorate and 5% sodium hydroxide.
6. A manufacturing method according to claim 4, wherein said removing step is achieved by means of tensile force applied to said oxidized conductor while said conductor is being wound.
7. A manufacturing method according to claim 4, wherein said removing step is achieved by means of righting moment attributable to the elasticity of the curved conductor itself.
8. A Conductor for electric power cable, substantially as hereinbefore described with reference to the accompanying drawings.
9. A method for manufacturing a conductor for electric power cable, substantially as hereinbefore described with reference to the Examples.

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